

**GLOBAL POSITIONING SYSTEM SUPPORTED
PILOT'S DISPLAY**

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ABSTRACT

This paper describes the hardware, software and operation of the Microwave Scanning Beam Landing System (MSBLS) Flight Inspection System Pilot's Display. The Pilot's Display is used in conjunction with flight inspection tests that certify the Microwave Scanning Beam Landing System used at Space Shuttle landing facilities throughout the world.

The Pilot's Display was developed for the pilot of test aircraft to set up and fly a given test flight path determined by the flight inspection test engineers. This display also aids the aircraft pilot when hazy or cloud cover conditions exist that limit the pilot's visibility of the Shuttle runway during the flight inspection. The aircraft position is calculated using the Global Positioning System and displayed in the cockpit on a graphical display. The runway, desired flight path, and "fly-to" needles are displayed for the pilot, as well as other information used by the flight inspection test engineers. A variation of the software and hardware also aids the pilot to fly inspection flights for Tactical Air Navigation ground stations at the Shuttle landing sites.

INTRODUCTION

Requirement

The Pilot's Display Subsystem is part of the Microwave Scanning Beam Landing System (MSBLS) Flight Inspection System and is used to coordinate the test requirements of the inspection team with the test aircraft pilot. The test requirements consist of radials (wherein the aircraft flies toward the runway at a constant altitude) and glide slopes (which are landing approaches at set angles; see figure 1). This display shows the pilot the correct flight path to fly

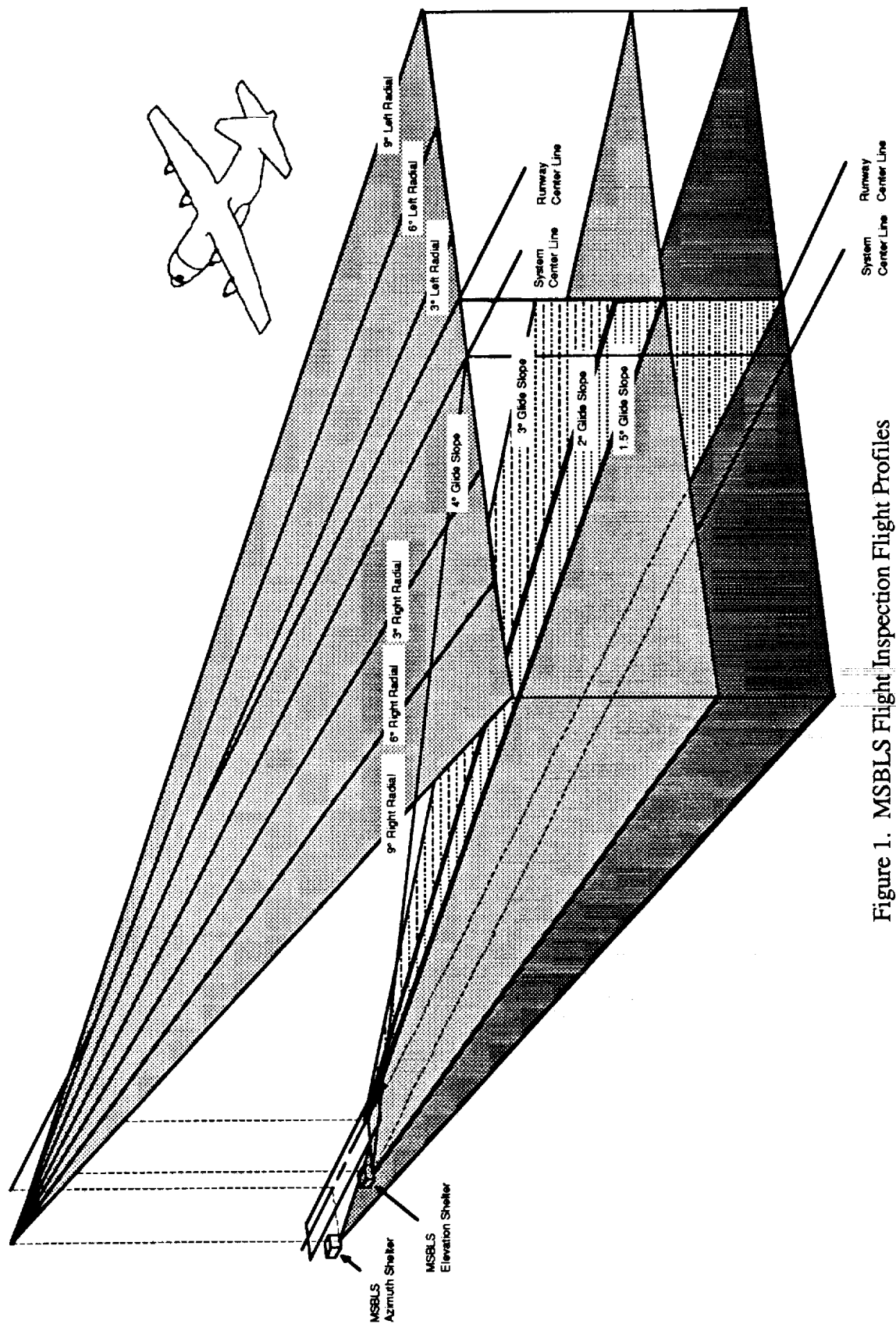


Figure 1. MSBLS Flight Inspection Flight Profiles

and provides "fly-to" needles so the aircraft can remain on the correct flight path during the different flight inspection test runs.

Aircraft Position Determination

The Pilot's Display, as well as the MSBLS Flight Inspection System, uses Global Positioning System (GPS) data to determine aircraft position in real-time. The GPS operates by the use of 21 satellites, when fully deployed, in 12-hour orbits that continuously broadcast their identification, position, and time in space. The position of the aircraft is determined by receiving the information transmitted by any four of the satellites and by computing the position using the orbital information the satellites provide and the time the information takes to travel from the satellite to the aircraft.

GPS Errors

The GPS satellites transmit information on two frequencies: 1575.42 MHz (L1) and 1227.60 MHz (L2). The L1 carrier contains a precision code (P-code) ranging signal and a coarse/acquisition (C/A) code. The L2 carrier contains only the P-code, which is intended for military use only. The GPS receivers used by the MSBLS Flight Inspection System can receive only the L1 frequency and process only the C/A code. The use of the two frequencies allows a GPS receiver that receives both L1 and L2 carriers to compensate for the effects of the ionospheric and tropospheric delays and greatly improve the accuracy of the computed position. This type of GPS receiver can also correct for another source of error called selective availability (SA). The SA is an intentional error placed in the satellite's information, and only receivers that can process the P-code are able to correct for this error in real-time.

Differential GPS

The effects of the GPS errors described in 1.3 and a few others can be reduced for those with only C/A receivers (receives only L1 carrier) by using a technique called Differential GPS, which is the technique used by the MSBLS Flight Inspection System. Differential GPS uses two C/A receivers, a receiver located in a user vehicle and a reference receiver at a known fixed location. Since both receivers see the same errors, the reference receiver calculates the errors from the information about its known location and transmit the error information to the user receiver to correct its calculated position. A set of GPS receiver equipment is located at the MSBLS elevation transmitter shelter (see figure 2) and a set is located in the aircraft with MSBLS receivers and decoders. This configuration of equipment sets up the GPS data in the differential mode for the MSBLS flight inspections.

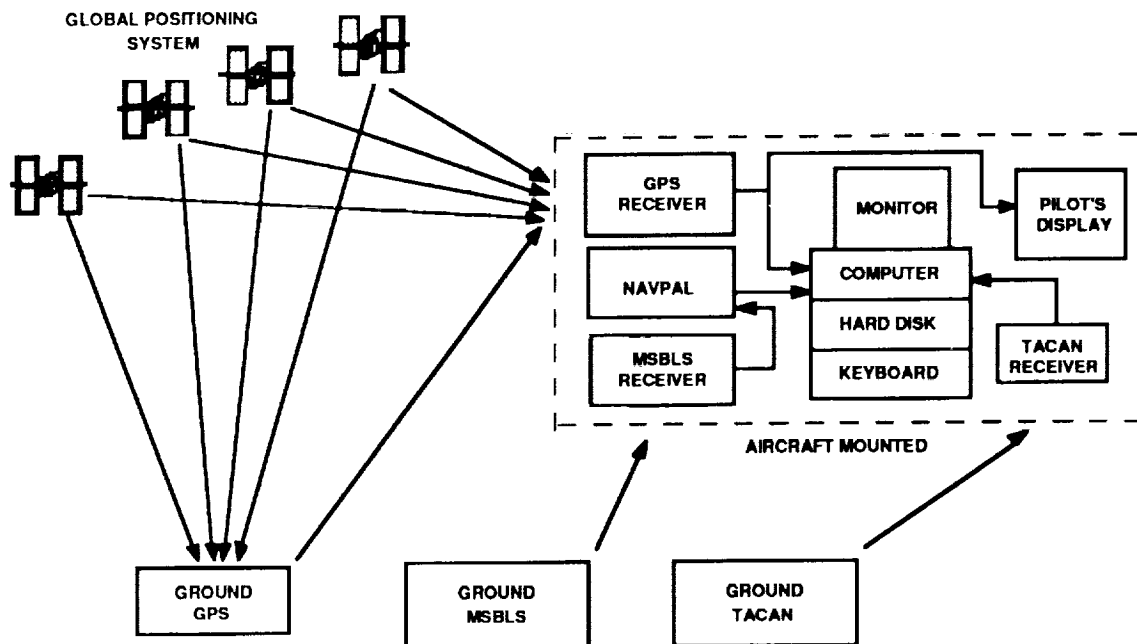


Figure 2. MSBLS Flight Inspection System

THEORY OF OPERATION

System Configuration

The Pilot's Display (see figure 3) receives the GPS position data from the same GPS receiver used by the MSBLS Flight Inspection System. The GPS receiver is initialized by the MSBLS Flight Inspection System computer and is set to receive and compute position data from satellites along with correction data from the reference receiver. The GPS receiver provides coordinate data (corrected X, Y, and Z in differential mode) to the system computer over an RS-232 serial data link at a data rate of 9,600 baud. The ground GPS receiver/modem (reference receiver) is initialized as the origin of the Pilot's Display coordinate system. The ground GPS receiver/modem will transmit position corrections for the coordinate system based on bias and drift errors in the GPS signal.

Display

The Pilot's Display computer is programmed to compute and display the aircraft's position in real-time on a video monitor. The display shows a pair of "fly-to" needles (see figure 4). The distance of each needle from the center of the display represents the aircraft's offset from the desired flight path. These offsets are computed once per second and are the differences of the aircraft's computed position and the chosen flight path. The pilot corrects the course of the aircraft by flying the aircraft so the needles move toward the center of the display as the error in the flight path is reduced.

Pilot's Monitor

The output of the computer color monitor card is sent to a graphics format conversion card (Folsom Research, Inc., Video 300 Card), which converts the computer graphics format to television NTSC format signals. The Video 300 card outputs a standard NTSC video signal which is sent over coax cable to the aircraft flight deck to the pilot's color monitor (5-inch JVC TM-63U).

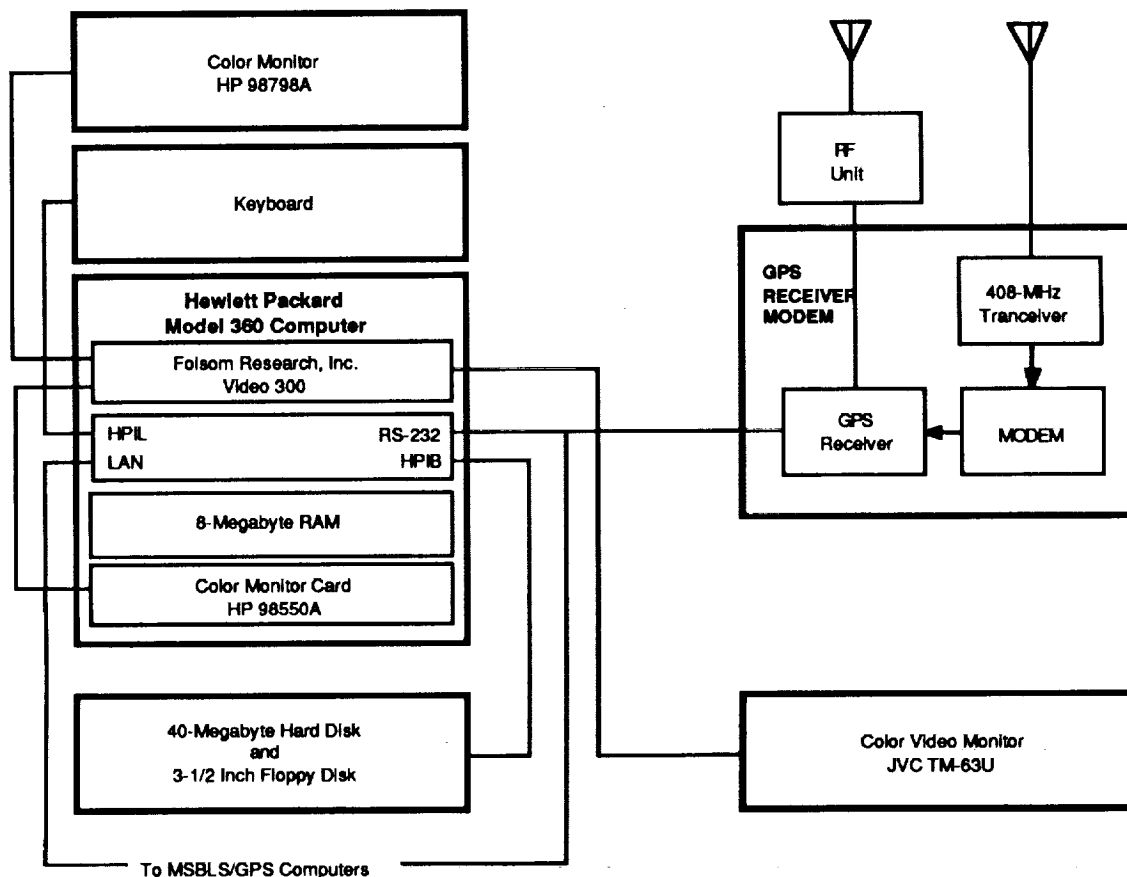


Figure 3. Pilot's Display System Block Diagram

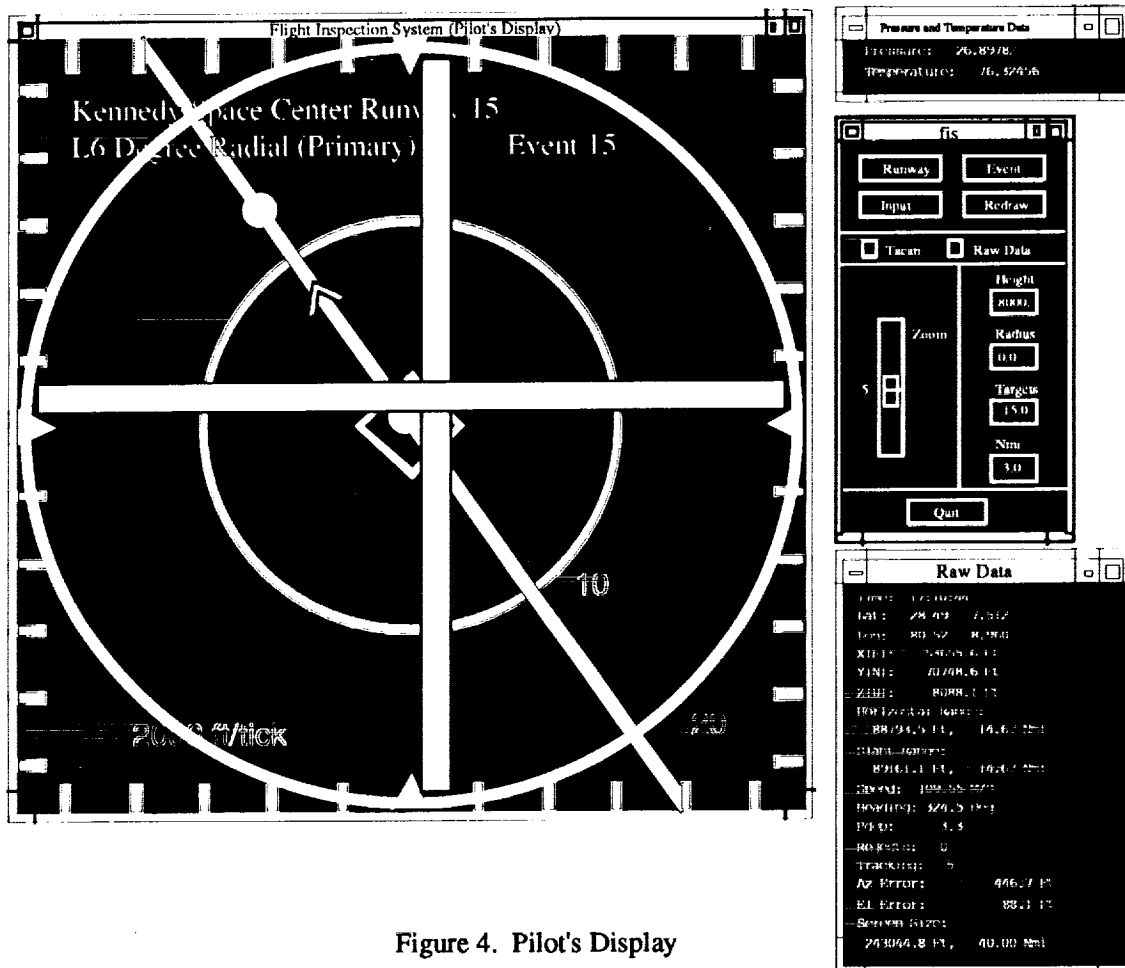


Figure 4. Pilot's Display

SOFTWARE DESCRIPTION

System Inputs

The pilot's display program uses GPS information from a GPS receiver to provide real-time updates of the position of the aircraft. To accomplish this, the pilot's display program reads the data coming from the GPS receiver via a 9600 baud serial link between the receiver and the pilot's display computer. The non-position information contained in the data stream is filtered out and the remaining information is used to determine the aircraft's position. This information appears about once a second in the data stream. The program can also replay GPS information previously recorded to a file. This file can only contain GPS position data and is not filtered in any way. The data will be replayed at about five times its normal rate of once a second.

The pilot's display computer is also connected to an analog to digital (A/D) converter that is connected to temperature and pressure transducers. The A/D converter is connected to the pilot's display computer via a HPIB link. During real-time data display it is queried whenever a position update is received on the GPS data stream (once a second) and the information is displayed to the operator and logged to a file, along with the current time (from the GPS data), for later analysis.

Operator Inputs

The pilot's display program runs in the X Windows Version 11 Release 3 (X11R3) environment and uses the Motif graphical user interface (GUI). When the program starts it presents the operator with an empty pilot's display and the operator's control panel. The program is controlled from the control panel via the mouse and/or the keyboard. The control panel has control buttons and sliders that control the operation of the pilot's display. A button is selected by either moving the mouse cursor on it and clicking the mouse button or by pressing the tab key on the keyboard until the desired button is highlighted and then pressing enter to select the button. The operator can perform the following program control actions from the control panel:

- a) Select runway (Runway). Upon selection of this button, the operator will be presented a scrolling menu window of runways to select from. The runways are loaded from a database on the pilot's display computer and can be updated at any time to include new runways or to modify the characteristics of existing ones. Once a runway is selected, the pilot's display program will display the runway on the pilot's display and begin taking data from the currently selected GPS data stream, updating the aircraft's position as necessary. The runway database information was obtained from the Defense Mapping Agency Geodetic Survey Group, Detachment 4, Patrick Air Force Base, Florida, "Survey Results, Space Shuttle Support," dated January 1990.
- b) Select event (Event). Upon selection of this button, the operator will be presented a scrolling menu window of flight path events to select from. The events are loaded from a database on the pilot's display computer and can be updated at any time to include new events or to modify the characteristics of existing ones. Each event is identified by an event number and description. If the currently selected mode is TACAN mode, then only TACAN events are displayed. If the mode is not TACAN, then all other events are shown. Once the event is selected, the flight path is displayed on the pilot's display, along with the "fly-to" needles.
- c) Select input source (Input). This button allows the operator to select either real-time data mode or playback mode. This button will present a file selection window to the operator to allow the selection of another input source. If the operator selects the serial connection that the GPS real-time data is received then the program will operate in real-time mode. If the operator selects a file of recorded GPS data, the program will operate in playback mode. In real-time mode, GPS data is taken until the input source is changed. In playback mode, GPS data is taken from the file until the end of the file and no further updates occur until the operator selects another input source.
- d) Redraw pilots display (Redraw). This button causes all the windows used by the pilot's display program to be cleared and redraw.
- e) Select/Deselect TACAN mode (Tacan). This button controls whether TACAN events are selected when the Event button is pressed. This this button is in the pressed state TACAN mode is selected, else it is not.

f) Select to see raw GPS data (Raw Data). This button allows the operator to control whether a window displaying the raw GPS data is displayed. If the button is in the pressed state the a raw GPS data window will be displayed, else it will not be.

g) Change zoom factor (Zoom). This is a slider that has a range from one to ten and controls the scale of the pilot's display.

h) Change event characteristics (Radius, Height, Target In, Target Out). These text entry fields afford the operator the ability to change certain characteristics of the current event. These changes are only in effect as long as the current event remains selected.

Program Calculations

The program for the pilot's display calculates distances and errors by translating the raw GPS data and comparing it to the selected runway and event information. The raw GPS data gives position in longitude and latitude and this information is converted to local east, north and up (x,y,z) coordinates.

The program calculates two types of deviation: elevation and azimuth. Both are measured in feet. Elevation deviation is the distance that the aircraft is above or below the flight path. Azimuth deviation is the distance that the aircraft is to the left or right of the flight path.

Elevation deviations are calculated two different ways, each for a different type of flight event. If the event has no glide slope, then the elevation deviation is simply the difference between the desired height and the actual height. For glide slope events, the only difference is that the desired elevation has to be calculated based upon the aircraft's distance.

Azimuth deviations are handled in two different ways each for a different type of flight event. If the flight path is radial (i.e., a straight line), the difference between the aircraft's heading and the desired flight path heading is calculated rotating the aircraft's position about the system origin by an angle equal to the sum of the runway heading and the desired aircraft heading.

If the flight path is circular, azimuth deviations are calculated by determining the distance of the plane from the system origin and subtracting that from the desired distance. The sign of the deviation is determined by calculating the angular difference between the aircraft's heading and a tangent to the circular flight path.

CONCLUSIONS

MSBLS flight inspections have become more efficient with the Pilot's Display. The display coordinates the test engineer's requirements with the pilot of the test aircraft and provides the pilot a direct indication how well he is maintaining the test flight. This system has also been used to follow the progress of the aircraft while flying from one Shuttle Landing Facility to another, demonstrating the use of GPS as a navigation aid.